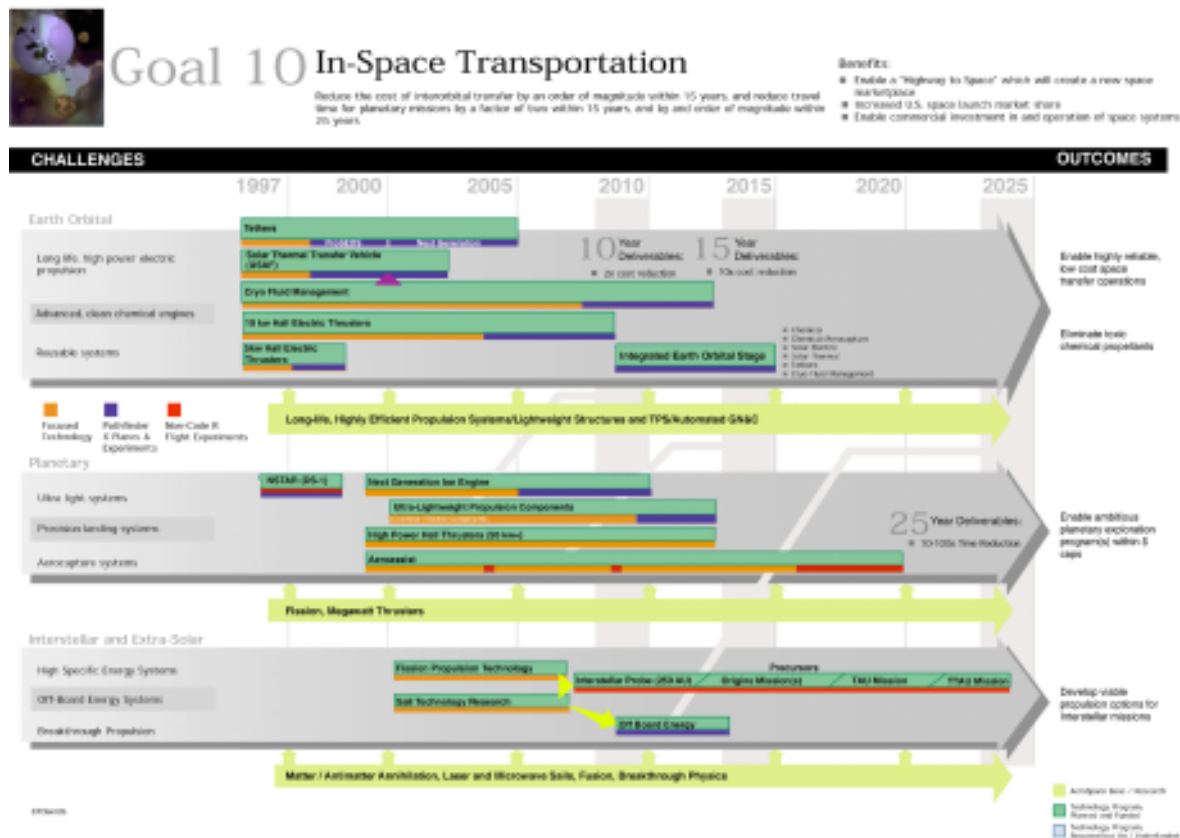




Goals and Objectives

- ◆ The Upper Stage Technologies Project has been initiated to support developing and demonstrating technologies for near term application to low cost upper stages . This includes hybrid and hydrogen peroxide engine technologies.

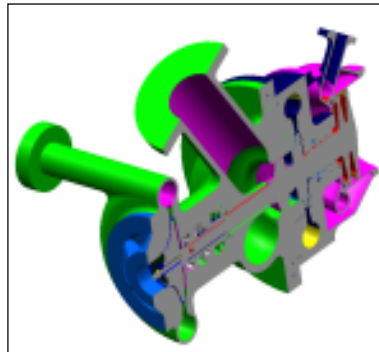




Two Focused Investments

◆ Peroxide/RP Propulsion

AR2-3 Test Program
Boeing Rocketdyne SAA



Advanced Catalysts,
Ignitors, & Turbopumps
Boeing Rocketdyne CA
Aerojet CA
TRW/GK/Purdue FFPC
FMC FFPC

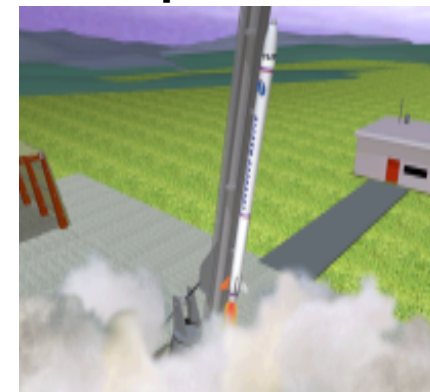
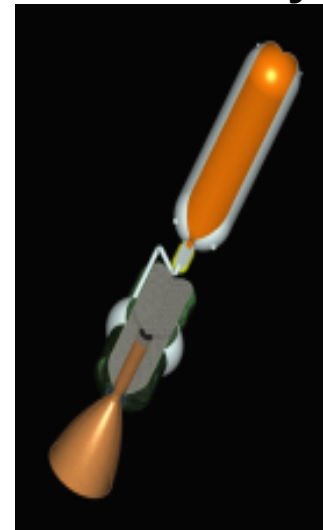


Upper Stage
Flight Experiment

- Pressure fed engine
- Common bulkhead composite structures

Orbital Sciences-I FCC

◆ Peroxide/Hybrid Propulsion



Hybrid Sounding
Rocket (HYSR)
LMMSS-SAA



LMA/Thiokol/Boeing-IFCC

250K Test Program
HPDP Consortium-CA



- ◆ **Develop and demonstrate advanced (98% concentration) peroxide based propulsion systems**
- ◆ **Demonstrate safer operations than comparable Lox based systems**
- ◆ **Maintain low cost/high operability focus**
- ◆ **Accommodate industry interest in peroxide propulsion system development**
- ◆ **Coordinate Air Force and NASA peroxide engine technology development**
- ◆ **Develop expendable hybrid design with comparable performance to peroxide/RP designs**



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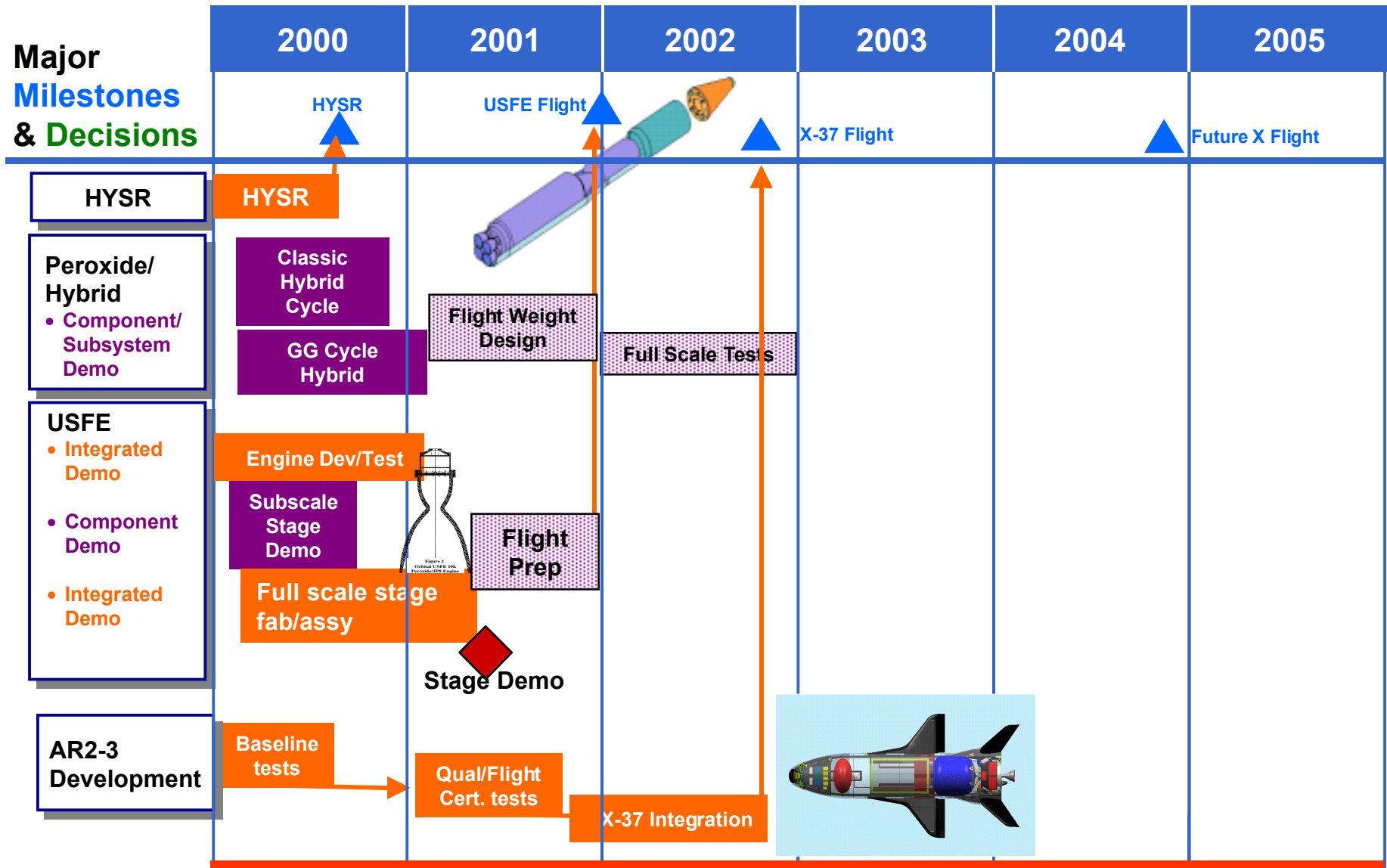




Peroxide Propulsion Roadmap

Upperstage Technology Project

2000 PMC





Major Accomplishments FY98/99/00

Upperstage Technology Project

2000 PMC

Progress

Planned Date	Actual date	Accomplishment	Significance
November, 1998	December, 1998	AR2-3 Space Act Agreement Signed	Initiated jointly funded propulsion research by NASA and Boeing Rocketdyne
June, 1999	September, 1999	AR2-3 Testing Begins	First test of pump-fed peroxide propulsion system in 20+ years
August, 1999	October, 1999	AR2-3 Testing Ends	AR2-3 main chamber catalyst pack is nonfunctional. Boeing begins failure investigation and redesign.
September, 1997	December, 1997	USFE contract signed	First contract signed for peroxide based propulsion system demonstration in more than 30 years.
November, 1998	January, 1998	USFE System Concept Review held	Flight demonstration system concept fully defined and development requirements flowed down to key subsystems, especially the propulsion and structures subsystems.
March, 1998	March, 1998	Orbital 10k Engine PDR held at Kaiser Marquardt	First design review of new pressure fed peroxide/RP engine design in 30 years.
February, 1998	April, 1998	Orbital/Kaiser Marquardt Catalyst Tests begin at the Navel Weapons Center.	Catalysts are the key technology to the design and operation of peroxide based propulsion systems.
May, 1998	September, 1998	Orbital/Kaiser Marquardt Catalyst Tests complete	Kaiser successfully identifies a catalyst design suitable for bi-propellant subscale tests.
May, 1998	August, 1998	Orbital/Kaiser Marquardt Subscale Engine Tests begin	These are the first tests of a newly designed peroxide based bi-propellant thruster in 30 years.
August, 1998	October, 1998	Orbital/Kaiser Marquardt Subscale Engine Tests complete	Kaiser successfully identifies a catalyst design suitable for bi-propellant subscale tests.
August, 1998	October, 1998	Orbital 10k Engine IDR held at Kaiser Marquardt	Updated engine design based on Kaiser catalyst and subscale engine tests reviewed.
August, 1998	August, 1998	Orbital/Kaiser Composite Subscale tanks completed	First ever peroxide compatible composite oxidizer tanks successfully fabricated.
September, 1998	September, 1998	Orbital contract modified for Augmentation test series	Additional risk reduction hardware and tests added to the Orbital contract.



Major Accomplishments FY98/99/00

Progress

Planned Date	Actual date	Accomplishment	Significance
October, 1998	December, 1998	Orbital 10k Engine Augmentation test series begins	First full scale tests of 10k engine begin. Initial results are unsatisfactory. Catalyst design and supplier changed and engine eventually performs satisfactorily.
February, 1999	June, 1999	Orbital 10k Engine 140sec test complete	Longest continuous test of a peroxide/RP engine with ablative chamber/nozzle
Unplanned	July, 1999	Orbital 10k Engine Augmentation test series suspended	Orbital testing suspended in order to begin testing of Boeing Rocketdyne AR2-3
August, 1999	August, 1999	PDR for subscale structure demonstration held at OSC	Subscale structural demonstration configuration established along with design and test requirements
October, 1999	December, 1999	Orbital contract modified for subscale structure and peroxide enrichment skid efforts.	Implements additional NRA8-21 Cycle 2 technology selection
October, 1999	January, 2000	CDR for subscale structure demonstration held at Aspect engineering	Design and process details for subscale structure demonstration reviewed.
October, 1999	January, 2000	Kick-off meeting held at Degussa for enrichment skid.	Enabling technology for future peroxide development.
October, 1999	November, 1999	Aerojet catalyst tests performed at Naval Weapons Center	First tests of monolithic substrate catalysts system performed on Aerojet IRAD funds. Results are unsatisfactory.
September, 1999	December, 1999	Aerojet Cooperative agreement signed	Implements NRA8-21 Cycle 2 technology selection
September, 1999	November, 1999	TRW contract signed	Implements NRA8-21 Cycle 2 technology selection.
December, 1999	January, 2000	TRW kick-off meeting held	Initiates catalyst effort by TRW/General Kinetics/Purdue University team.
January, 1999	March, 1999	Hybrid Sounding Rocket (HYSR) Space Act Agreement	Commits MSFC/SSC/WFF to support of LMMSS large scale hybrid motor demonstration
May, 1999	May, 1999	HYSR program kick-off meeting held at LMMSS	Kick-off meeting for all program participants including briefing on HYSR configuration and development schedule
October, 1999	January, 2000	Pressurization system testing completed	Key subsystem development completed.
January, 2000	January, 2000	Test motor poured at SSC	First motor of this size prepared at SSC.



Major Accomplishments FY98/99/00

Upperstage Technology Project

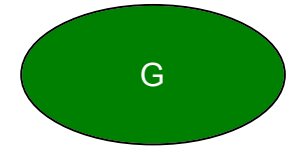
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Progress

Planned Date	Actual date	Accomplishment	Significance
Unplanned	June, 1998	HPDP cooperative agreement modified to move test program to SSC and reduce NASA's participation in the program	NASA's role reduced to SSC test support and MSFC manpower redeployed to other efforts
December, 1998	July, 1999	First 250k motor test complete at SSC	Motor 1 evidenced immediate instability at start-up. Test only 6 seconds in length. Additional modifications and retest being proposed.
February, 1999	August, 1999	Second 250k motor test complete at SSC	Motor 2 tested successfully for 15 Seconds.
April, 1999	September, 1999	Third 250k motor test complete at SSC	Motor 2 test begins with stable operation but goes unstable during the 35 second burn. Additional modifications and retest being proposed.



◆ Milestone: Complete Orbital 10K engine development augmentation test series



- **Completion:** March, 2000
- **Output:** Completion of the Augmentation Test Series will provide the design data necessary to complete the final design of the flight weight 10K lbt. pressure-fed USFE peroxide/JP8 engine. The data will establish the final fuel/oxidizer mixture ratio, the throat contraction ration, the throat length and diameter, the injector configuration, the engine valve timing, and the purge system flow rates and timing.
- **Outcome:** Completion of the development testing of the USFE 10K engine will move the maturity of peroxide/JP8 pressure-fed propulsion closer to commercialization. The commercial application of this technology could enable a ten-fold reduction in upper stage transportation system costs, thereby directly contributing to NASA's Goal 9 for Space Transportation.
- **Status:** Orbital engine in test now at SSC. Planned completion mid-Feburary



◆ Milestone: Complete Orbital 10K engine development

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- **Completion:** March, 2001
- **Output:** Completion of the Orbital 10K engine development will provide an operating example of a flight weight 10K lbt. Pressure-fed peroxide/JP8 engine. This engine configuration will then be available to industry for immediate commercial application to DoD, NASA, or commercial missions.
- **Outcome:** Completion of the development testing of the USFE 10K engine will move the maturity of peroxide/JP8 pressure-fed propulsion closer to commercialization. The commercial application of this technology could enable a ten-fold reduction in upper stage transportation system costs, thereby directly contributing to NASA's Goal 9 for Space Transportation.



◆ Milestone: Complete Orbital USFE Stage Demonstration

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- **Completion:** June, 2001
- **Output:** Completion of the USFE Stage Demonstration will provide an operating example of a very low cost Pressure-fed peroxide/JP8 stage design. This stage configuration will then be available to industry for final development and commercial application to DoD, NASA, or commercial missions.
- **Outcome:** Completion of the USFE stage demonstration will move the maturity of peroxide/JP8 pressure-fed propulsion and integrated composite integral bulkhead stages closer to commercialization. The commercial application of this technology could enable a ten-fold reduction in upper stage transportation system costs, thereby directly contributing to NASA's Goal 9 for Space Transportation.



◆ Milestone: Complete Boeing Rocketdyne AR2-3 testing

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- **Completion:** December, 1999
- **Output:** Baseline performance data for the AR2-3 operating with 90% peroxide and JP8 will be generated. This data will include chamber pressure, mixture ratio, combustion temperatures, catalyst efficiency, ignition delays, and turbine efficiency.
- **Outcome:** The AR2-3 engine is the only man-rated reusable rocket engine in the US inventory with operating times measured in minutes rather than seconds. As such it is an excellent platform for evolution of a long life reusable engine for reusable upper stage applications. An evolved AR2-3 engine with a design life in excess of 100 missions would directly contribute to the Agency's Goal 9 for a ten-fold reduction in space transportation costs.
- **Status:** Engine testing completed in November. But engine not functional--main catalyst pack failure. Funding of effort transitioned to X-37 program for completion.



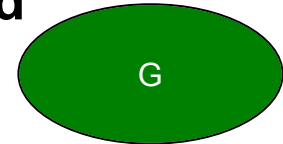
◆ Milestone: Complete Aerojet and TRW catalyst development

- **Completion:** June, 2000
- **Output:** One or more catalysts will be developed for the repetitive decomposition of 98% peroxide. These catalyst will then be available to industry to perform a number of higher propulsion and environmental functions.
- **Outcome:** Peroxide's future use in industry as an oxidizer of choice is directly tied to the utilization of 98% peroxide. Only at the 98% concentration is peroxide superior in density impulse performance to today's propellants. The technology challenge lies in developing efficient catalysts for the repetitive decomposition of peroxide. These catalyst can then be used to provide onboard power, drive turbopumps, provide attitude control, heat, water, and/or oxygen. An integrated system design providing all of these functions from a single oxidizer tank will substantially simplify systems and between flight processing. This in turn will lower between flight processing costs and directly contribute to NASA's Goal 9 for Space Transportation.
- **Status:** Aerojet testing began in November. Initial results were unsatisfactory. Kick-off meeting held at TRW in January, 2000.

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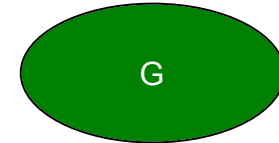
◆ Milestone: Complete Orbital peroxide enrichment skid demonstration



- **Completion:** December, 2000
- **Output:** A peroxide enrichment skid which will supply 98% peroxide to support NASA/industry/Air Force technology development.
- **Outcome:** Peroxide's future use in industry as an oxidizer of choice is directly tied to the utilization of 98% peroxide. Only at the 98% concentration is peroxide superior in density impulse performance to today's propellants. The development of systems to provide onboard power, drive turbopumps, provide attitude control, heat, water, and/or oxygen are dependent on a reliable supply of 98% peroxide for research. An integrated system design providing all of these functions from a single oxidizer tank will substantially simplify systems and between flight processing. This in turn will lower between flight processing costs and directly contribute to NASA's Goal 9 for Space Transportation.
- **Status:** Kick-off meeting held at Degussa Huls in January, 2000. SSC preparing siting plan.



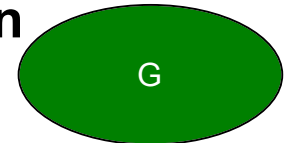
◆ Milestone: Complete initial 250K Hybrid testing



- **Completion:** December, 1999
- **Output:** The Hybrid Propulsion Demonstration Program (HPDP) Consortium has been successful at developing subscale hybrid motors with acceptable efficiency and stable operation. This test program will determine whether the design tools and processes developed during the subscale motor development can be used for large scale hybrid motors.
- **Outcome:** Lox/hybrid motors are storable, like solids, but safer with the segregated oxidizer. Lox/hybrids are restartable like liquid propulsion systems, but have lower cost due to the solid propellant. Lox/hybrids offer the potential for a five fold reduction in upper stage propulsion costs from over a \$1m for a solid to less than \$200k for a hybrid. This can directly contribute to a reduction in space transportation costs--NASA's Goal 9.
- **Status:** Third and final test of initial series completed in September, 1999. Both tested motors evidenced instability. Proposals are being prepared by the HPDP Consortium to modify and retest the motors. Proposals expected 31 January.



◆ Milestone: Complete LMMSS HYSR flight demonstration



- **Completion:** September, 2000
- **Output:** HYSR flight demonstration will establish the ability of a large single stage Lox/hybrid sounding rocket to perform the same missions typically performed by multi-stage solid rocket motor sounding rockets.
- **Outcome:** Lox/hybrid motors are storable, like solids, but safer with the segregated oxidizer. Lox/hybrids are restartable like liquid propulsion systems, but have lower cost due to the solid propellant. A large single stage Lox/hybrid sounding rocket can perform the same missions as multi-stage solid propellant sounding rockets with much higher personnel safety. Lox/hybrids offer the potential for a three fold reduction in sounding rocket propulsion costs relative to today's multi-stage solid propellant systems. This can directly contribute to a reduction in space transportation costs--NASA's Goal 9.
- **Status:** Development tests of pressurization system completed in January 2000. Development motor successfully fired in January, 2000. Motor test preparations now underway.





Peroxide/RP-The Best Packaged Power

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